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HARVESTING AND DRYING ROUGH RICE IN CALIFORNIA

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INTRODUCTION

It has generally been recognized by rice millers that the milling quality of rough rice is related to its field history as to moisture and temperature conditions before and after the rice is harvested. The purpose of the work reported here was to make a study of the different methods of harvesting and drying rough rice in California and to determine the relation between milling quality and the methods of harvesting and drying.

Rice production in California is confined to a few counties along the Sacramento and Feather rivers, with the exception of a small acreage in the Merced Irrigation District, south of Merced. Large tracts of land in the Sacramento Valley meet the requirements for successful rice production, being favored with an abundance of irrigation water, good drainage, high temperatures during the growing season, a subsoil impervious to water, and a surface easily leveled, so that it can be flooded to a uniform depth. Conditions in many sections of the San Joaquin Valley are very favorable to rice production, with the exception of water supply; 6 to 8 acre-feet of irrigation water are required annually.

Because of the alkaline soils and other unfavorable conditions, a large part of the acreage devoted to rice production is suitable for no other purpose. Rice is naturally resistant to small amounts of alkali, and the large amounts of fresh water used for irrigation keep the alkaline salts washed out. Because alkali is hygroscopic in nature also, an excess interferes with the drainage of the fields at maturity and thus delays harvesting operations.

As the growing season in the Sacramento Valley is too short for the long-grain or Honduras types of rice now extensively grown in the South, only the short-grain types, known as California-Japan rice, are produced. In the past, California-Japan rice has not been very popular in the domestic market; but during the last few years its popularity has steadily increased. This type of rice commands a premium in several

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foreign markets. Ordinarily about 70 per cent of the annual crops is exported, most of it going to the Hawaiian Islands and Porto Rico, when conditions are normal. Japan buys a considerable part of the California crop when its own production is below normal.

Rice was first grown commercially in this state in 1912, when the production totaled 35,000 bags. In 1930 the amount was approximately 3,000,000 bags. The acreage planted varies considerably from year to year; approximately 125,000 acres was the total in 1931. The average acre yield in California is approximately one and one-half times the average for the United States as a whole. In general, rice grown in the Sacramento Valley is not ready for harvesting until the first part of September. Harvesting in some sections often continues as late as November 15. Natural conditions for drying become less favorable as the fall season advances: rains are liable to occur; fogs become more prevalent and last longer during the day; and the average temperature is lower. In some years, early fall rains make the harvesting of the rice practically impossible; and that which is harvested is of very poor quality, often spoiling after it is threshed and stored in the warehouse. On the other hand, the harvesting season may be attended by extremely warm, dry weather, which causes the rice to dry too fast. When rice is subjected to high temperatures and dried rapidly, the structure of the kernel is broken, producing what is termed "sun-check," one of the factors contributing to poor milling yield. It may safely be said, accordingly, that weather plays the most important part in the harvesting of the crop.

Jones[3] reports that rice has a tendency to require a certain length of time from seeding to maturity, regardless of the date of seeding, but that yields from the earlier seeding are higher. Wateribune rice, sown as early as soil conditions permitted, produced a 9-year average of 400 pounds per acre more than that sown on the second seeding date, 15 days later; and 500 pounds per acre more than that sown on the third date, 30 days later. The later-sown rice was of consistently poorer quality than the earlier-sown. Early-sown rice, in addition to producing higher yields, matures sooner, so that the danger of losses from fall rains is reduced and, in turn, some of the possible trouble which might otherwise be experienced in the harvesting of the crop is eliminated.

A good drainage system is essential to rice production, especially to harvesting.[4] When rice is mature, the fields should be ready to sup-

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[3] Jones, Jenkin W. How to grow rice in the Sacramento Valley. U.S.D.A. Farmers' Bul. **1240**:13. 1924.

[4] Weir, W. W. Drainage in the Sacramento Valley rice fields. California Agr. Exp. Sta. Bul. **464**:35–36. 1929.

port the harvesting machinery—a condition possible only when the system of drainage is properly laid out and adequate. Mature rice, if not harvested at once, is subject to lodging, sun-checking, unseasonable rains, and loss from birds. The general practice is to begin draining the fields before full maturity. Ten days to two weeks are sufficient for dewatering the crop when the drainage system is adequate. Well-leveled land and an adequate system of drains aid in the harvest because, under such conditions, very few wet spots will be left in the field to retard the movement of the harvesting machinery.

Three different methods are used in the harvesting of California rice, namely: cutting with a binder and threshing with a stationary thresher; harvesting direct with a combined harvester-thresher, which will be referred to in this publication as a combine; cutting with a windrower and threshing with a combine having a windrow pickup attachment.

BINDING

Prior to 1929, practically all the rice grown in California was harvested with binders and shocked. After curing in the shock from ten days to two weeks, the grain was threshed with stationary threshers. This system is still commonly followed.

The binders used are similar in construction to the ordinary grain binder. The bull-wheel is usually provided with lugs to prevent side-slipping and is covered with disks fastened to the spokes to prevent mud from rolling up on the inside of the wheel. Shields around the chains and gears prevent clogging with mud. Practically all machines are equipped with small auxiliary gasoline engines having an average rating of 5 horsepower. These engines provide all the power necessary for operating the binder, except that for pulling it through the field. Some machines are driven through a power take-off from the tractor. The tractive power obtained from a binder bull-wheel traveling in a wet rice field is insufficient for the cutting and binding mechanisms.

Power for pulling the binder through the field is provided by a light tractor or by horses. In some instances the binder is mounted on the front end of the tractor, receiving power for operation either from an auxiliary engine or from a power take-off on the tractor. When the latter arrangement is used, no standing rice is run over and lost in making the first cut around the checks. This feature is important in sections where the checks are small, because of the large number of checks that must be opened.

Loss of Rice in Binding.—Binding is at best a wasteful practice. Estimates of the usual loss are from 5 to 12 per cent from shattering, from trampling of bundles and of standing rice, from skips, and sometimes from imperfect binding of the cut rice. In addition, unless the checks are very large, the waste is due to knocking down rice in opening the checks. The amount of shattering may be reduced by growing non-shattering varieties and by harvesting before the rice is overripe.

The use of a push-binder is the obvious means of minimizing waste in the opening round.

Studies of field losses resulting from harvesting Colora rice with a binder were conducted at the Cortena Rice Station over a period of two years,[5] 1927 and 1928. A pan was installed in the binder at the junction of the platform and elevating drapers; another pan was installed at the juncture of the seventh roller and the deck, to catch any grain or heads that might otherwise fall to the ground. The binder was adjusted to operate with a minimum loss of grain.

The grain lost in shocking was determined by catching the shattering grain as the bundles were picked up and the shock was erected. Most of the loss occurred as the bundles were lifted from the stubble.

In collecting the loss of grain from the shock to the thresher, the bundle racks were equipped with tight bottoms to retain the loose grain. The total loss from binding, shocking, and hauling was 72.9 pounds per acre from a field yielding 3,577 pounds per acre, or 2.04 per cent of the total yield. Seventy-five per cent of this total loss occurred at the binder head. The other 25 per cent was evenly distributed among shocking, hauling, and the other pans on the binder. These losses do not include those resulting from opening checks and from thresher losses.

The conditions under which these tests were conducted would probably show a minimum loss for binding because of ideal conditions throughout the harvest. The moisture content of the rice at the time of binding averaged 21.2 per cent, decreasing to 13.8 per cent when the grain was threshed ten days later.

A loss in excess of 50 per cent was shown in an overripe field in which harvesting was delayed because of rain. This loss resulted not only from shattering of overripe grain at harvest time, but also from excessive lodging and wind shatter.

Drying Rate of Rice Straw and Grain in Shocks.—During the 1927 harvest, samples of rice and straw were taken from the center of bundles in shocks from two adjacent plots. Plot 1 was fertilized with 150 pounds

[5] Stirniman, E. J., and C. F. Dunshee. Loss of rice in binding. Agr. Engin. 10(10):325–326. 1929.

of sulfate of ammonia per acre, while plot 2 was unfertilized. The fertilized plot had the appearance of maturing a few days later than the unfertilized. Due to the fact that a different bundle was sampled each day and that samples from the same bundle may have variations in moisture content, the data are somewhat irregular. However, the results show that under favorable weather conditions, a period of from 80 to 100 hours in the shock is desirable before threshing. The moisture con-

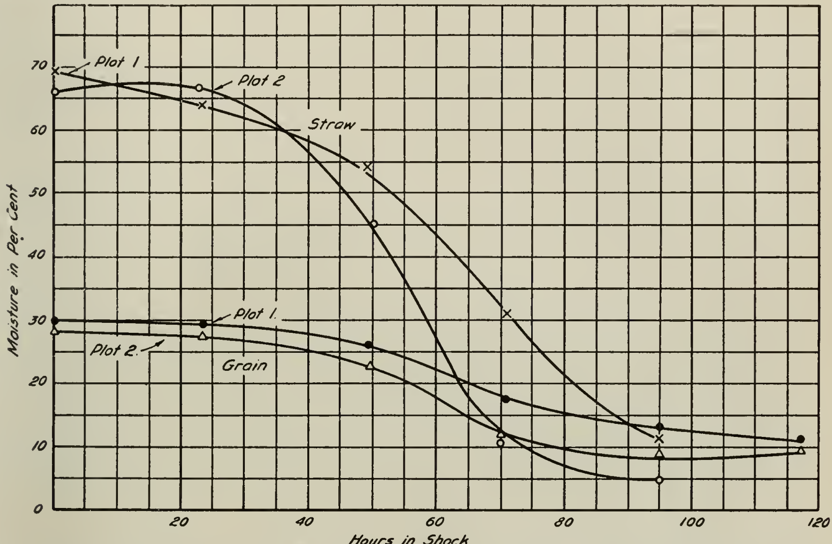

Fig. 1.—Drying rate of rice straw and grain in shocks. Plot 1, fertilized with 150 pounds sulfate of ammonia; plot 2, unfertilized. October 9–14, 1927.

tent of the grain when bound (fig. 1) was 28 per cent in plot 2 and 30 per cent in plot 1. The percentage of moisture decreased to 9.6 and 11.4 per cent, respectively, for the two plots at the time of threshing. The straw had a moisture content of 65 and 70 per cent when bound, decreasing below that of the grain after 80 to 90 hours in the shocks. The final moisture content of the straw when threshed was 4 to 5 per cent lower than that of the grain.

COMBINING

The combine was first used to any great extent by rice growers for harvesting rice during the 1929 season, when approximately 3,000 acres were harvested by this method.

This experience was so successful that in the 1930 harvest season approximately 25,000 acres were harvested by combines, and in the 1931 harvest season approximately 35,000 acres were thus harvested.

In practically all cases, the rice was first windrowed and then, after drying for 3 to 8 days in the windrow, was threshed by a combine equipped with a pickup. Under this system the moisture content in the rice was reduced to a point where safe storage of the threshed grain was made possible.

Direct combining was possible when the moisture content in the standing rice was below 15 per cent, or when some means of artificial drying of the threshed grain was available. Often near the end of the harvest season, the moisture content in the standing grain was as low as 11 or 12 per cent. In these cases there was no reason for first windrowing the grain before threshing it. Near the close of the 1930 and

Fig. 2.—Combining rice direct.

1931 harvest seasons, which, like the 1929 season, were very favorable to combining, a large proportion of standing rice was dry enough for direct combining. In one instance, when the moisture content of the standing rice continued to remain around 12 to 14 per cent, the windrowing was discontinued, and the rest of the crop was combined direct (fig. 2).

One rice grower in the Sacramento Valley has installed a rice drier, which makes it possible to combine direct before the rice is dry, hauling the wet rice immediately to the drier, where the excess moisture is removed. The moisture content at the time of cutting ranges from 20 to 25 per cent. This figure is reduced to between 14 and 15 per cent while the rice is passing through the three-stage, forced-draft drier.

Windrowing.—As soon after draining as the soil is dry enough to support the weight of machinery, the checks are usually opened by means of a push-type header, mounted on the front of a tractor (fig. 3).

If this type of machine is used, very little grain is knocked down and run over during the first trip around the check. The cutter bar on this type of header is usually about 2 feet longer than the platform and draper. The draper travels toward the extended end of the cutter bar. As the machine has no elevator, the cut grain is simply carried to the end of the platform, where it is allowed to fall to the stubble.

The grain that is cut by the extension on the cutter bar falls back over the bar to the stubble. This 2-foot strip then makes up the base of the windrow, while the remainder of the swath is cut and conveyed by the draper and allowed to fall on top of the 2-foot strip, thus finishing the windrow. This procedure simplifies the picking-up operation, since

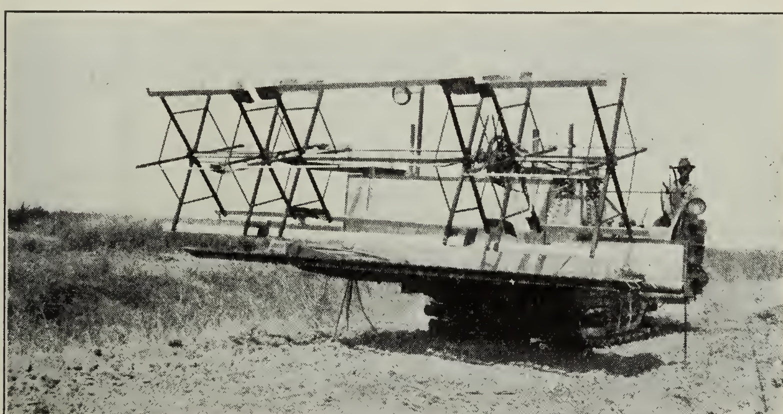

Fig. 3.—A push-header used for opening up checks. The cutter bar has a 2-foot extension on the left end.

the whole windrow is cut free and deposited on the stubble. It also helps to eliminate waste in the field. If the header is 12 feet in width, with a 2-foot extension, a 14-foot swath is deposited in a windrow about 3 feet wide.

After one trip around the check with the push-header, another round is made with the header traveling in the opposite direction. In this second operation another windrow, similar to the first, is deposited beside the first. This procedure brings together the rice from a swath 28 feet wide into two windrows side by side, thus providing sufficient clearance for the operation of the other harvesting machinery.

The greatest drawback to this method of opening the checks is that the windrows, being so close together, dry out rather slowly because of a poor circulation of air. Considerable trouble is usually experienced in threshing these double windrows as compared to single windrows.

Windrowing of the remainder of the check may be continued with the push-headers. The general practice, however, is to continue to open checks with the push-header and to use ordinary windrowers for completing the cutting of each check (fig. 4).

The windrower is similar in design to the header on the harvester. Often, in fact, it consists of the harvester-header, equipped with an auxiliary engine for driving the cutting mechanism, reel, and draper, and a large bull-wheel for carrying the end of the header that was previously attached to the harvester. An adjustable shield over the short elevator controls the position of the windrow relative to the windrower.

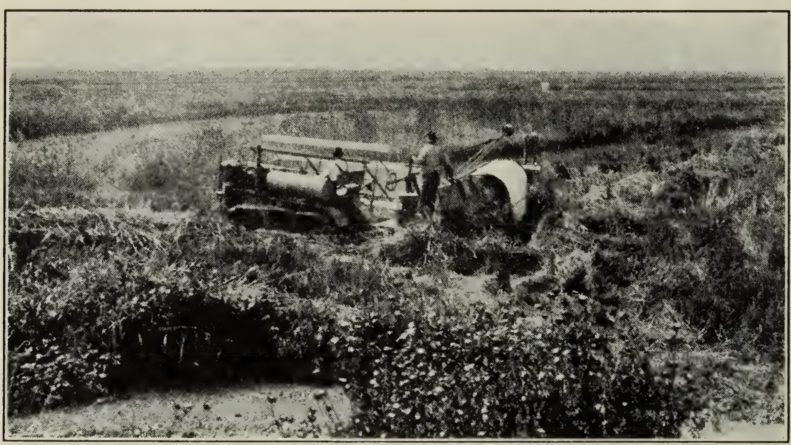

Fig. 4.—Windrowing a small rice check. Making a square turn.

An offset type hitch enables the windrower to be pulled by a tractor, at the same time allowing the tractor to clear the standing grain.

On the larger harvesters the header is usually too long for windrowing, since the average size of the rice check is small. Unless the checks are unusually large, headers with cutter bars longer than 12 feet are hard to manage. Then, too, a windrow in average rice, containing more than a 12-foot swath, requires more time for drying and is more difficult to thresh. When the harvester header is too wide to be converted into a windrower, a smaller machine must be provided. These windrowers may be obtained from the different harvester companies in widths to meet any condition. In general these machines resemble the built-up machines in which the harvester header is used.

Because of adverse footing conditions, tractors having 20 to 30 horsepower on the drawbar are required to provide ample power for pulling the windrowers. A tractor with a very short turning radius is needed in

order that sharp turns may be made in harvesting small and irregular checks. Track-laying type tractors meet the requirement for short turning, as well as giving good traction on the wet soil. A speed of 3 to 4 miles per hour is used in the windrowing operation.

In the hitching of a windrower to a tractor, care must be taken not to let the windrow fall into the tractor track; otherwise, drying will be slower, and difficulty will be experienced in picking up the grain for threshing. Furthermore, when this condition does prevail, it necessitates the running of the pickup so close to the ground that small lumps

Fig. 5.—A rice windrow supported by stubble.

of dirt may be picked up with the rice. The picking up of mud lumps may be prevented by changing the position of the tractor relative to the position of the windrower, or by extending or shortening the elevator shield on the windrower. The latter method is more commonly followed.

The method used in seeding rice plays an important part in the success of the windrow pickup system. Rice seeded broadcast, either by the common broadcaster, or by airplane, is more easily handled than rice that has been planted with a drill. The stubble of the broadcast field is irregular in arrangement and therefore gives a better support for the windrow, while the stubble of a drilled field has a tendency to separate, especially when the windrow is deposited parallel to the drill rows. In other words, adjacent drill rows separate by falling in opposite directions, allowing the newly made windrow to come in contact with the ground. Once the rice falls through the stubble, the pickup cannot pos-

sibly recover all of it. The whole theory of windrowing is to allow circulation of air around the cut grain to hasten drying (fig. 5). If the windrow falls through the stubble, circulation of air beneath the windrow is stopped.

Drying Rate of Rice Straw and Grain in Windrows.—During the 1930 harvest samples of rice and straw were taken from the top and bottom of a windrow, over a period of 120 hours to determine the rate of drying in different parts of the windrow. The rate of drying depends to a large extent upon the temperature, humidity, and wind velocity. The

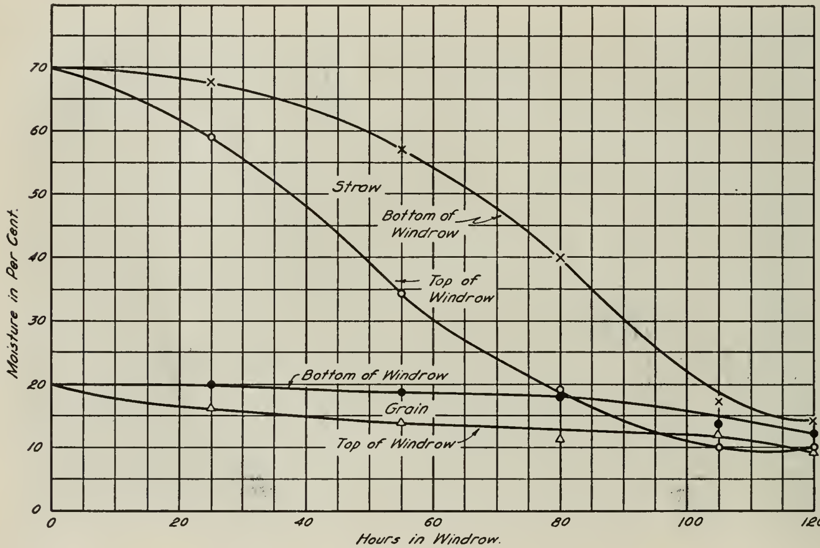

Fig. 6.—Drying rate of rice straw and grain at the top and at the bottom of a windrow. October 1–5, 1930.

moisture content of the grain at the time of cutting was 20 per cent. The moisture content of the grain at the time of threshing this particular windrow was 10 per cent for that in the top of the windrow and 12.8 per cent for that in the bottom. Threshing could have taken place 80 to 85 hours after windrowing when the average moisture content was 15 per cent. The moisture content of the straw at the time of windrowing was 70 per cent, while at the time of threshing, 120 hours later, the straw contained an average of 12.5 per cent moisture (fig. 6).

Threshing from the Windrow.—After 2 to 6 days in the windrow, according to the original moisture content and the weather conditions, the moisture content in the rice has usually dropped below 15 per cent. When this moisture content is reached, the pickup and threshing operation may be safely started.

A combine equipped with a pickup attachment is used for gathering up and threshing the windrowed rice (fig. 7). This pickup consists of a short platform and elevator with a draper, which attaches to the combine in the same place and manner as the regular header. The pickup mechanism is attached to the front of this short platform. It is usually 6 or 7 feet in width. Steel tubes or cross bars extend the full width of the pickup, ranging from 8 inches to 12 inches apart, and are attached to special links in the link-belt chains driving the pickup mechanism. The tines or fingers that pick up the windrowed grain are spring steel,

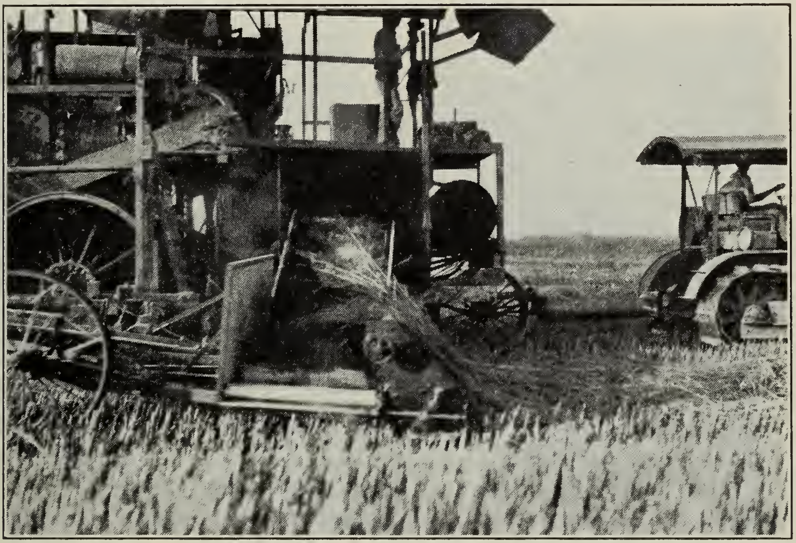

Fig. 7.—Threshing rice from the windrow by means of a combine equipped with a pickup.

wrapped several times around the steel tubes. These tines have very flexible points 4 to 6 inches long and are placed at 6-inch intervals on the cross bars. The correct angle is given the tines by an arrangement of crank arms and cams at the ends of the cross bars carrying the tines. The free ends of these arms are equipped with rollers running in guides. As the tines move along the back side of the pickup frame, they are folded against the frame. Upon reaching the windrow, the crank arrangement turns them at right angles to the cross tubes. They remain at right angles during the picking-up and elevating operation. When the end of the elevating operation is reached, the crank and cam arrangement causes the position of the tines to change, allowing the tines to pull out of the portion of the windrow being raised and afterwards assuming the original position for travel back to the windrow. The tines should

travel at a speed only sligthly greater than the forward speed of the harvester. With a proper speed the tines handle the windrow very gently, causing practically no shattering. The picking up of the windrow is so continuous that the windrow resembles a ribbon flowing into the machine. The height of the pickup is controlled by a tiller wheel within reach of the combine operator.

The threshing is done with the ordinary combine. A few changes, however, better adapt this machine to rice threshing. To prevent the cracking of the rice, the speed of the cylinder is reduced approximately 25 per cent below that used for threshing wheat and barley. Special rice concaves and cylinders are sometimes used. They contain fewer teeth and easily effect the correct clearances for rice threshing.

In general, the transmission of power on harvesters is from the harvester engine direct to the cylinder and then from the other end of the cylinder to other parts of the machine. In the slowing down of the cylinder, other parts are slowed down accordingly. To prevent this hindrance and to maintain the capacity of the separating chamber, a larger sprocket is necessary on the end of the cylinder shaft that drives the rest of the machine. If, for example, the cylinder is slowed down 25 per cent, a sprocket having 33.3 per cent more teeth must be supplied in place of the regular sprocket on the cylinder so that the normal separation speed may be maintained.

More agitation in the separating chamber is desirable for the threshing of rice than for wheat or barley, because of the usual dampness of rice straw. Especially is this statement true of rice that is being combined direct at a time when the moisture content of the rice straw is as high as 75 to 80 per cent. Observations made on two machines combining rice direct showed that practically all of the thresher losses resulted from the inability of the combine to separate the threshed rice from the straw, once the rice was knocked out of the heads in passing through the cylinder. In these particular cases the combines alone could not be blamed, because the operators were crowding the machines in an effort to complete harvest before inclement weather set in. The machines did not, however, have enough agitation to shake all of the rice through the heavy, damp straw.

Clearances under the combine are important in rice harvesting because of the possibility of the heavy combine miring into the mud when wet spots in the field are encountered. In one particular make of harvester the lowest part of the machine was the fan which furnished air to the lower cleaning shoe. Experiences with this machine, which had only 12 inches of clearance, showed this clearance to be insufficient. On sev-

eral occasions the machine dropped down until so much of its weight was carried on the fan housing that the housing was bent and the fan broken. This combine was finally abandoned for harvesting rice in the 1930 harvest because of this one factor. Previous to the 1931 harvest the owner of this particular harvester raised the machine with reference to the wheels by inserting 6-inch blocks between the harvester frame and the axle. This increased the clearance to 18 inches, which was sufficient to eliminate the trouble that had previously been experienced. Protection in the form of a heavy steel skid under the fan housing might have been provided to carry this weight when the machine sank down, or wheels having more bearing surface might have been installed.

One of the chief drawbacks to the windrow-pickup system is that threshing rice from the windrow is usually a relatively slow process. Ordinarily only 10 to 15 acres can be handled per day. The rice checks are usually small, ranging in size from ½ acre to 15 acres, so that a great amount of time is lost in turning corners and moving from one check to another. Heavy dews and fogs delay starting in the mornings until 9 or 10 o'clock and sometimes until noon. Again, threshing cannot be continued after 8 o'clock in the evening, for the straw becomes tough because of absorbed moisture. The speed in the field usually ranges from 1½ to 2 miles per hour, which results in a relatively low duty for machines.

During the 1929 and 1930 harvest seasons, one harvester sometimes handled as many as 600 acres of windrowed rice; but this practice is not to be recommended. The chances are too great that inclement weather might set in and the rice be lost. Then, too, enough equipment should be available to get the rice off as soon as the proper moisture content is reached, in order to eliminate as far as possible the sun-checking of the kernels. Three hundred acres is about the maximum that can be handled safely by one harvester; preferably, the acreage should be below this figure. Unless the harvester can be used on some other crop in addition to rice, its use will probably not be economical because of its low duty.

Loss of Rice in Combining.—As observations on combines harvesting rice direct were limited to only three machines, no conclusive data on this method can be given as to losses of rice. Two of these machines, one a 7-foot cut, the other a 10-foot cut, were threshing rice which was yielding better than 50 sacks per acre. These machines were being crowded because of a late start. The losses on them ranged from 3 to 4.5 per cent, the chief cause being inability of the machines to separate the threshed rice from the straw. No particular difficulty was experienced in knocking the rice kernels out of the heads. The other machine was a large com-

bine with a 24-foot cut, threshing rice which was yielding approximately 30 sacks per acre. Here the loss amounted to less than 1 per cent. Ample time was given for complete threshing of the rice.

Blanket tests made on five harvesters threshing from windrows showed losses ranging from 0.1 to 1.0 per cent. The greatest loss occurred in the early morning and late evening. The losses in the windrow were practically negligible when the windrow was well supported on the stubble. Just what would happen to rice handled by this system if wet weather should set in, cannot be forecast, because the weather throughout the 1929, 1930, and 1931 harvest season was ideal for this method of harvesting.

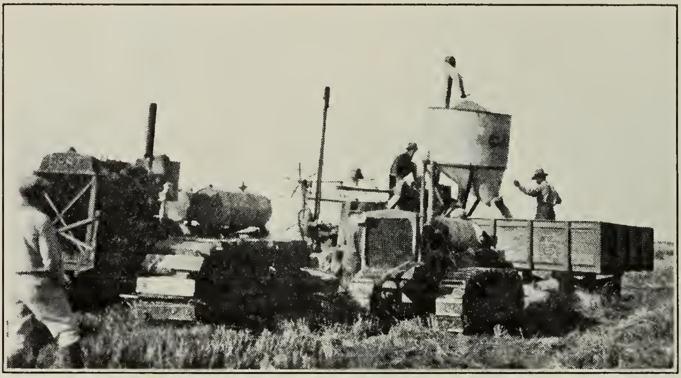

Fig. 8.—Handling rice in bulk. Sledding through the wet field to a transfer station on the hard road.

The proper adjustment and operation of the machines was the controlling factor as to the extent of the losses.

Handling the Threshed Rice.—Paddy rice may be handled either in bulk or in sacks. When it is handled in bulk, the harvester equipment must be provided with a bulk bin. A loaded bulk bin adds considerably to the weight of the combine, a fact which must be considered in providing power in the field, as well as in providing proper bearing surfaces for carrying this added weight on soft ground. Hauling equipment having a bulk bin is also necessary (fig. 8).

To eliminate this added weight on the harvester, one grower provided large canvas bags made with zipper fasteners. One man was required on the harvester to fill and close the bags. The bags were picked up, placed on a sled pulled by a tractor, and sledded to a transfer bin equipped with a portable elevator. Here they were quickly opened and their contents poured into the hopper of the portable elevator and elevated into the transfer bin. Large trucks then hauled the paddy from

the transfer bin to the elevator. The bags are used over and over and should last for several seasons.

Experience with the bulk handling of rice in well-drained fields showed that the system is practical. A saving of $3.00 to $4.00 a ton was shown. Some of the other advantages of the bulk system are as follows: rice in bulk may be cleaned more readily and rapidly than sacked grain. The system induces more of the cleaning to be done on the farm, which produces for the market, rice of a higher quality. Screenings and weed seeds are retained on the farm and can be used as a feed for livestock, while at the same time, the cost of freight on these two items is saved. It assists materially to have rice in bulk if artificial drying should become necessary.

So far as keeping quality is concerned, rice with a moisture content below 15 per cent may be handled safely either in sacks or in bulk. A lot of several thousand bushels of rice, combined direct and artificially dried, was safely stored in large bulk bins. This lot of rice went into storage with a 15 per cent moisture content.

On the other hand, rice threshed with only 9 to 11 per cent moisture and stored in large bulk bins has very little chance of absorbing additional moisture from the air during the damp winter weather, while sacked rice may take up from 2 to 6 per cent if the original moisture is low, because of the proximity of air to the sacks. Nine per cent moisture content seems rather low, but much of the rice handled by the windrow-pickup method in both the 1929 and 1930 harvest season contained moistures running that low. However, rice containing 10 per cent moisture as it went into sacks, showed 14 per cent moisture after a few weeks of wet weather—a gain of 4 per cent moisture, which gave a gain in weight of 4.65 pounds per 100 pounds of rice. At the same time, rice placed in large bulk bins did not show this gain, but remained practically constant. The average moisture content of 686 truckloads of rice, coming from five harvesters, threshing windrowed grain over a period of 14 days, was 11.6 per cent. The minimum moisture for this period was 9.8 per cent; the maximum, 15.5 per cent.

COST OF HARVESTING

The data on harvesting and threshing operations given below are based on the experimental area under observation. The costs include operating charges, labor, interest on the investment, and depreciation of the machinery.

The cost for harvesting rice by the binder-thresher system, including binding, shocking, hauling, and threshing ranged from $15.00 to $20.00 per acre, according to the acreage, yields, and weather conditions.

The cost for windrowing varied from $1.25 to $1.75 per acre.

The cost of threshing from the windrow ranged from $3.50 to $5.00 per acre, providing the harvester had other duties to which a part of the depreciation and interest on the investment could be charged.

DRYING RICE BY ARTIFICIAL METHODS

Occasionally, early fall rains catch part of the rice crop before it has been harvested. Sometimes these rains occur during the period the rice is curing in shock; or, if the windrow-pickup method is used, in the windrow. The result is that rice threshed when these conditions prevail usually contains an excess of moisture. If this moisture is in excess of 15.0 per cent at the time of storage, whether in bulk or in sacks, spoilage is likely to occur, especially if damp weather continues after storage takes place.

Rice that contains excess moisture does not give the best milling results. After a shelling test, rice with an original moisture content of 22.6 per cent showed only 17.0 per cent whole kernels; or 50.6 per cent whole and broken kernels. After drying to a moisture content of 15.3 per cent, the same lot of rice, when tested, showed 63.2 per cent whole kernels; or 79.8 per cent whole and broken kernels. Thus when this rice was dried down to a safe moisture content for storage, the per cent of the whole kernels from the shelling tests increased from 17.0 per cent to 63.2 per cent.[6]

On an average, rough or paddy rice consists of about 20 per cent hulls and 80 per cent brown rice. When the moisture content is high, the kernels of brown rice are broken up to some extent in the removal of the hulls. When pulverization occurs, some of the brown rice is aspirated off with the hulls, causing a loss of milled rice.

When the direct combine method is used in harvesting rice, artificial drying is necessary unless the moisture content is low enough to allow the crop to be safely stored. If the direct combining is done when the rice is in a stage of maturity considered suitable for windrowing, then the rice must be dried artificially, because the moisture content at this stage may be over 20 per cent.

[6] Bates, E. N., R. M. Gehl, and G. P. Bodnar. Bulk handling and artificial drying of rough rice on a farm at East Nicolaus, California. A preliminary report. Bur. Agr. Econ., U. S. Dept. Agr. 9 p. (mimeo.). 1928.

Rice containing an excess of moisture can be successfully dried artificially. An artificial rice drier installed by one grower in the Sacramento Valley enables him to combine his rice direct and then to reduce the moisture content to a safe point for storage. At the same time, he has absolute control over the final moisture content in the rice. For example, he may stop the drying operation when the rice reaches a desired point, taking advantage of all the allowable moisture for grade. In other words, he is able to market all the allowable moisture as rice.

The greatest benefit from this system, however, is the yield of high-quality rice. Rice handled in this manner is removed from the fields before much sun-checking has occurred. It is sent immediately to the drier, where drying is done in three stages at very low temperatures under controlled conditions. By the reduction of sun-checking, the highest possible yields of head rice are obtained.

Handling the rice by the direct combine method has cut this grower's harvesting cost to a minimum. All the work of binding, shocking, hauling to the thresher, and threshing, is taken care of in this one operation. And once the rice is cut with the combine, all other dangers from field losses are eliminated.

When this system of harvesting is used, the most practical way of handling the rice is in bulk, at least until it reaches the drier. This method eliminates the labor of sacking grain on the harvester and then opening the sacks and dumping the grain at the drier.

Description of the Drier.—The rice drier included in this study was one that had been imported from Italy in 1927. It was installed by a rice grower at East Nicolaus, California. While this drier was designed primarily for drying rice, it can easily be adapted to the drying of other grains, simply by changing the rate at which the grain passes through, and by changing the temperature of the drying air to meet the conditions necessary for drying different grains. This drier has been used also for the drying of milo maize.

The drier consists of three drier stands; three 150-bushel, hopper-bottom bins, one located above each drier stand; discharge shuttles located at the bottom of each stand; a coke furnace; a multiblade fan; and a hot-air tunnel for conveying the mixture of furnace gases and air from the fan to the drier stands (fig. 9).

Each stand is partitioned off into 9 vertical chambers (diagram B, fig. 9). Chambers A, B, and C carry the hot air from the tunnel to all parts of the drier. Chambers 1, 2, 3, 4, 5, and 6 carry the grain from the hoppered bin above to the discharge shuttles below. The two partitions are solid, while the inside and outside walls of the rice chambers are

made of No. 8 mesh, reinforced wire netting, to allow the free passage of hot air through the column of rice. Each chamber containing rice is $12\frac{1}{2}$ feet high, 5 inches by 40 inches in cross section at the top, tapering out at the discharge end to 6 inches by 40 inches. This taper prevents the jamming and lodging of rice as it passes through the drier by gravity. The top of each hot-air column is sealed off with a piece of iron shaped in the form of an inverted V (diagram A, fig. 9).

Shuttles are located at the lower end of each rice chamber for controlling the rate of movement of the rice and discharging the rice, at the

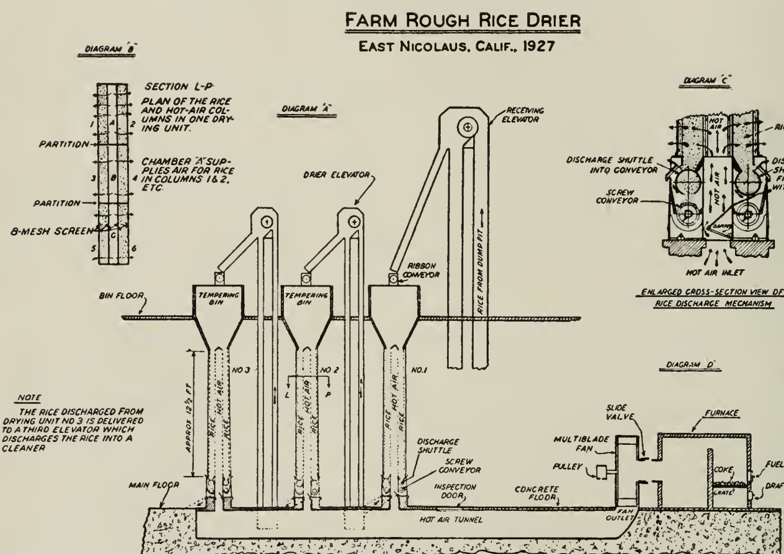

Fig. 9.—A three-stage drier. (Drawn by G. P. Bodnar, Bureau of Agricultural Economics, U. S. D. A.)

same time giving a fairly good seal at the lower end of the drier (diagram C, fig. 9). Two shafts, extending the full length of the drier, carry these shuttles, so arranged that there is one shuttle under each rice chamber. The discharge openings of the three shuttles on each shaft are spaced 120 degrees apart, so that in operation each of the screw conveyors receives three successive discharges of rice from each side during one revolution of the shaft. The rate at which the rice passes through the drier may be controlled by the speed of the shuttles.

Hot air for drying is furnished by a brick furnace in which the coke is burned. All the products of combustion are drawn from the furnace by a large multiblade fan and are forced into the hot air tunnel to be mixed with incoming cooler air before passing into the drier stands.

The correct temperature is maintained in the ingoing gases simply by allowing air from the room to pass through the fan into the tunnel to be mixed with the gases, whenever the temperature becomes too high. The tunnel is so constructed that the gases and incoming air will be thoroughly mixed in order to obtain a uniform temperature before reaching the drier stands.

Dampers located in the lower end of the air chambers in each stand enable the operator to control the admission of or shut off entirely the supply of hot air to any or all of the drier stands (diagram C, fig. 9). Hot air from the tunnel passes into the air chamber between the walls of rice and moves slowly through the grain to the outside air; in passing through, it absorbs moisture from the grain column.

Operation of the Drier.—For convenience in describing the operation of the drier, the stands are numbered from right to left (diagram A, fig. 9). Rice is elevated to the bin above stand No. 1, where a ribbon conveyor spreads the rice out evenly over the entire length of the bin. From the bin the rice is fed by gravity to the drying chambers. As soon as the drying chambers are completely filled the damper at the bottom of the hot air chamber is opened, allowing hot air to pass from the tunnel up into the center of the drier stand and from here it passes through the two columns of rice to the outside. After the rice in the stand is allowed to dry for a short period, the discharge shuttles (diagram C, fig. 9) are started. Screw conveyors located immediately below the shuttles carry the partially dried rice to one end, from where it is elevated into a bin located above stand No. 2. While the first stage of the drying operation is being started and until sufficient rice has passed through to fill stand No. 2, the dampers in Nos. 2 and 3 are kept closed to prevent the passage of hot air through the empty rice chambers. As soon as stand No. 2 and the bin above it are filled the damper is opened and the second stage of the drying begins. Stand No. 3 is likewise started. After all three stands have been put into operation, the drying process becomes continuous. The bins above Nos. 2 and 3 serve as a storage space for tempering the rice between stages of drying. At the end of the run the dampers are closed in the order of 1, 2, and 3, as each stand is emptied.

From the drier, the paddy rice is passed through the cleaner. Ordinarily one would think that the cleaning operation should come first; but the operator of this plant, having experienced some difficulty with the cleaner clogging up with damp foreign material, changed the order of procedure as a matter of convenience. After passing through the drier the chaff and straw are easily removed by the air blast from the cleaner.

The temperature of air admitted to the drier stands was maintained as nearly as possible at 90 degrees Fahrenheit. An adjustable slide valve on the intake side of the fan (diagram D, fig. 9) made it possible to draw in outside air to be mixed with the furnace gases for maintaining a constant temperature. A large volume of air is required for drying rice because of the low temperature used.

Temperatures of Drying.—A laboratory study was made to determine the maximum allowable temperature at which rice might be dried

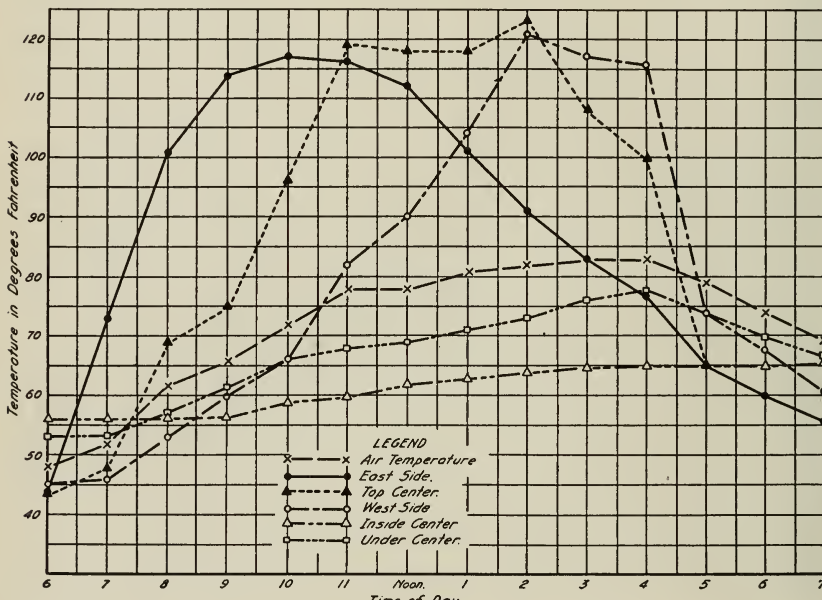

Fig. 10.—Temperatures in different parts of a rice shock at different times during the day. Cortena Rice Station, October 6, 1928.

without effect upon its milling quality. The rice used in these tests was taken from the field at different moisture contents. The drying temperatures used were as follows: room temperature (60°–90° F), 100°, 120°, 150°, and 185° F. The results showed that temperatures in excess of 100° caused a too rapid drying of wet rice, producing sun-checking of the kernels. The results were the same as those produced by too rapid drying when exposed to the sun. Temperatures well above 100° were found both in the shocks and in the windrows, even though the temperature of the surrounding air was not over 80° to 90° F. In the graph (fig. 10), the temperature on the top of the center of the shock is shown to be 124.5° at 2 p.m., while the temperature of the air had reached only 82°. Maximum temperatures were found to be in different places on the

shock as the day advanced. At no time did the temperature of the air exceed 83°. This phenomenon was due to the absorption of the sun's rays by the rice straw. Such a condition no doubt is a contributing cause of sun-checking. Samples taken from the shock at different points showed more sun-checking if taken from the areas in which the temperature became excessive than if taken from the interior and shaded portions of the same shock. Temperatures of 130° F were found in the top layer of a windrow when the temperature of the air was only 90°. Such conditions are entirely beyond the control of the operator.

Capacity of the Drier.—This drier has a capacity of approximately 500 sacks of paddy rice per 24-hour day, when reducing the moisture content 5 or 6 per cent. Fuel consumption under these conditions is about 1 ton of coke for a 24-hour run.

The power used for operating the drier consists of a 15 hp. motor for the fan, a 7.5 hp. motor for the discharge shuttles, and a 5 hp. motor for the three drier elevator legs and the three ribbon conveyors over the tempering bins.

The tunnel connecting the stands with the furnace has a volume of 500 cubic feet. The furnace has a grate surface of approximately 8¾ square feet.

Often during the warm part of the day very little or no additional heat is necessary for drying. In other words, the air that passed through the stands is drawn in at room temperature. This drier, including tunnel and furnace, covers a floor space of 525 square feet.

The rice coming from the drier, containing approximately 15 per cent moisture, was stored in 5,000-bushel bulk bins. No trouble was experienced with heating.

SUN-CHECKING

Rapid drying of rice kernels, either under natural conditions or by artificial means, sets up within the kernel certain stresses that tend to break down its structure. Small fractures, termed sun-checks, appear, and they usually occur in a plane perpendicular to the longitudinal axis. These fractures may be confined only to the interior of the kernel, but in most cases these minute internal checks separate sufficiently to extend the fracture through the surface (fig. 11). Rice kernels that have become checked are more apt to be broken in the milling operation than those that are sound.

A sample of milled rice (polished) purchased in a local store, showed a high percentage of kernels containing sun-checks, yet practically all of the kernels had passed through the milling operations without breaking.

Often the checking occurs in such a manner that two or more radial checks may be inter-connected with a lateral check (fig. 12). A rice kernel checked in this manner often breaks into several parts during the milling operation.

Fig. 11.—A kernel having no sun-check (left) compared with one having both an internal and an external check (right). The fracture shown in the upper part of the kernel is an internal check, while below it is an external check. Close observation will show the outline of the remainder of the kernel, below the external check. The dark section at the lower end of the kernel shown on the left is the embryo.

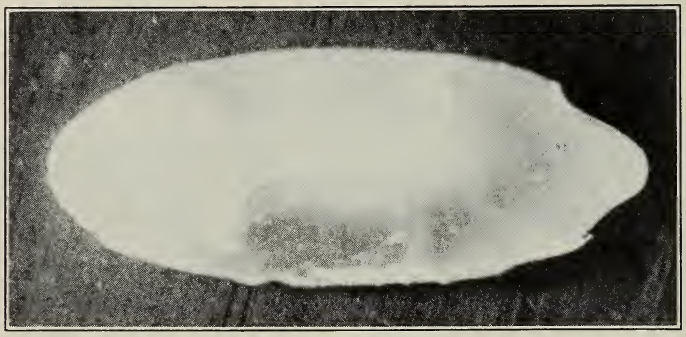

Fig. 12.—A rice kernel having an internal fracture with two radial checks inter-connected with the lateral check.

Since the value of rough rice is largely determined by the amount of "head rice" (whole kernels) which can be milled from the crop, its value decreases with the presence of kernels which will break up under the milling operation.

Breakage in milling the Japan or short-grain rice is less than in the Honduras or long-grain type, on account of the short, compact shape of the kernel. The whole grain content after milling varies from approximately 30 per cent to 70 per cent, according to the type and condition of the grain and the milling processes employed.

Although sun-checking in brown rice is not a positive indication of milling quality, it is a fair indication. A lot of rice may show a high percentage of sun-checked kernels, yet mill out fairly well, because of the nature of the sun-checks themselves. The sun-checks, though present in these cases, are internal in nature, not extending through the surface, and consequently do not break up so readily as other samples, containing fewer sun-checks but of an external nature.

Windrowed rice has more heads exposed to the direct rays of the sun than shocked rice, providing the shocks in the latter have been capped. This exposure causes a more rapid drying of the rice. Internal strains are set up in rice that is subjected to high temperatures of drying because insufficient time is given for the movement of moisture within the kernel itself. The sun-check results when temperatures are high and the moisture is removed too fast. The extent of the fracture depends upon the temperature and the rate of drying. The kernel may be fractured in more than one place; it may have a fracture that extends through the kernel; or it may have only a partial fracture. Because of these minute fractures, sun-checked kernels have a greater tendency to break down under the threshing and milling operations than sound kernels, especially in the latter operation.

Observation of the windrows showed a great deal more sun-checking in the upper layers of the windrow as compared to the rice, well shaded, on the underside of the same windrow. Samples taken from the top and bottom portions of the same windrow, under extreme conditions, showed a difference of 20 per cent in the yield of head rice in favor of the shaded grain. The longer the rice remained in the windrow after reaching the proper moisture content, the greater the difference between the top and bottom layers. Some of the rice windrowed in the 1929 season, before much experience had been gained regarding this method of harvesting, was left in the windrow as long as 18 days, fully two weeks after the moisture content in the grain was low enough for safe storage. The result was that this lot of rice sun-checked very badly because of the long and unnecessary exposure.

Rice, left standing in the field two to three weeks after conditions were right for harvesting, was found to be 75 to 100 per cent sun-checked when finally harvested. At the same time the moisture content of

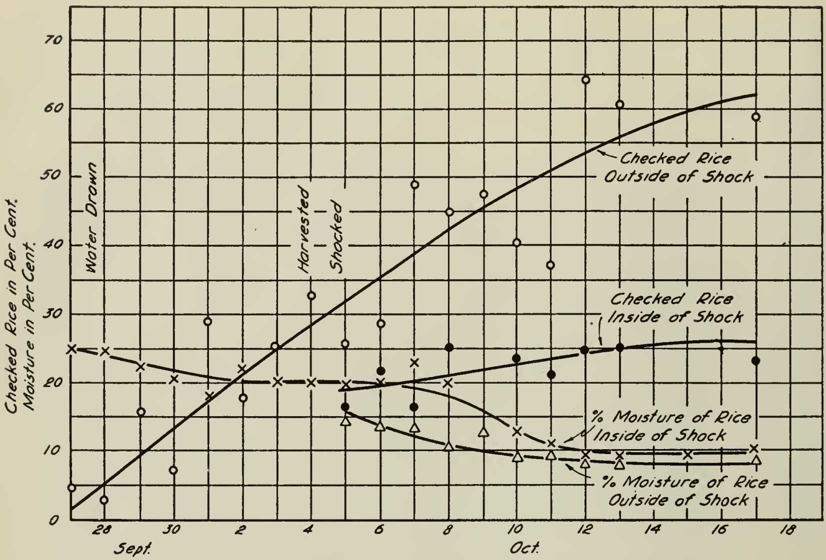

Fig. 13.—An analysis of bound rice to show moisture content and checking under field conditions. The water was drawn September 28. The rice was bound October 4, shocked October 5, and was threshed October 17, 1928.

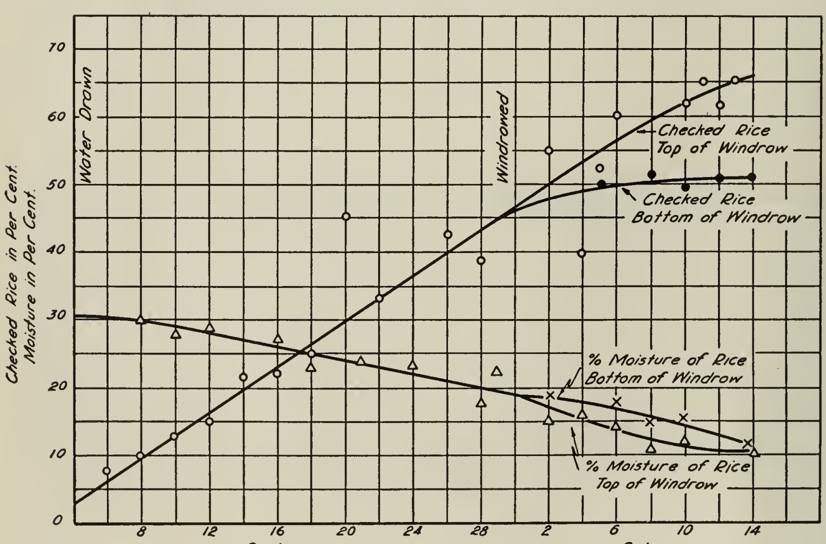

Fig. 14.—An analysis of windrowed rice to show moisture content and checking under field conditions. The water was drawn September 4. The rice was windrowed September 30, and threshed October 14, 1930.

the rice was found to be as low as 10 per cent. When the moisture content of the rice was allowed to fall below 11 or 12 per cent, whether immediately before or during the harvest period, a poor quality of rice usually resulted as sun-checking always occurred.

The windrowing process is so much faster than the picking-up process that care must be taken not to get too much rice cut in advance of the picking-up and threshing operation.

One rice grower attempted to produce a machine that would invert the windrow as it left the header spout. This provision allows the heads to fall first, later to be covered with the damp butts of straw, as the windrow is finished. A development of this type would no doubt assist materially in the production of a higher quality of rice by the windrow-pickup method. The rice kernels dry out much faster than the straw. In many cases the controlling factor as to when the rice in the windrow may be threshed is the moisture content in the straw. Threshing in the early morning and late evening often must be discontinued because the straw is too tough to pass readily through the machine. The greatest drawback to this system is that the heads are in position to receive and hold water from a rain. In a trial windrow built in this manner, water from a light shower ran down the stalks to the heads, where it was readily taken up. Rice handled in the ordinary manner was ready to thresh several hours before the rice in this trial windrow after the rain.

An analysis was made of bound and windrowed rice showing checking under field conditions (figs. 13, 14). In these studies the per cent of checked rice in different parts of the shock and windrow is shown by one group of curves, while the moisture content at different stages is shown by the other. The rice was left in both the shock and windrow six days longer than necessary, before threshing.

After three years' experience with the windrow system, general observations have shown that harvesting in this manner usually lags. For example, windrowing is usually delayed a few days later than necessary, after draining; in other words, the fields are dry enough for windrowing sooner than windrowing is ordinarily begun. Likewise, the threshing could usually have taken place from four to seven days before it actually starts. To produce the highest quality of rice by this system the operations must be timed and carried out as soon as conditions will permit.

During the 1931 harvest season four sets of moisture-testing apparatus were placed in different sections through the rice-growing section. Rice growers were encouraged to bring in samples of their rice at the time of harvesting for moisture determinations. Those who availed themselves of that privilege were able to progress with their harvesting

operations in a more intelligent manner, because they knew exactly when the moisture content was right for threshing or safe storage. The first tests run showed much lower moisture contents than was anticipated by the particular growers whose rice was tested. In most cases the farmers who availed themselves of this service speeded up their harvesting operations and at the same time produced rice of higher quality.

In the past years the price differential between head rice and screenings has been so small as to merit no great amount of serious thought; often it was only 50 cents per hundred pounds. During the past two years, however, a general overproduction of rice here and abroad has brought about a greater difference in price between these two grades.

SUMMARY

Weather plays the most important part in the harvesting of the rice crop.

A well-planned, adequate drainage system is essential to rice production, especially to the harvesting of the crop.

The method of seeding plays an important part in the success of the windrow-pickup system. Rice seeded broadcast, either by the common broadcaster or by airplane, is easier to handle than rice that has been planted by a drill. To facilitate rapid drying the windrow must be supported by erect stubble.

Three different methods are used in the harvesting of California's rice crop: namely, the binder-thresher method, the windrow-pickup in conjunction with the combine, and direct combining. At present, approximately 75 per cent of the crop is handled by the binder-thresher method and 25 per cent is handled by the combine. Practically all of the combined rice is first windrowed and then, after drying for 3 to 8 days, is threshed by a combine equipped with a pickup. Direct combining is possible when the moisture content in the standing rice is below 15 per cent or when some means of artificial drying is available.

A push-header with a 2-foot cutter bar extension mounted on the front of a tractor is the most satisfactory means for the opening of rice checks when the windrow-pickup method is used.

The cost of harvesting by the binder-thresher method varies from $15.00 to $20.00 per acre, while the cost of harvesting by the windrow-pickup method varies from $4.75 to $6.75 per acre.

In a study of losses from the windrow-pickup system, it was found that they may be held below 1 per cent if proper machine adjustments are maintained and if good weather prevails throughout the harvest

period, while the losses from the binder method vary from 2 to 10 per cent.

Only 10 to 15 acres can be handled per day when one is threshing windrows consisting of the grain from a 12-foot swath. Three hundred acres of rice is the maximum amount that one combine should be expected to handle.

More agitation in the separating chamber is desirable for the threshing of rice than for wheat or barley because of the usual damp condition of the rice straw.

Rice having a high moisture content does not give high yields of head rice since it lacks resilience to withstand the milling process.

Rice containing an excess of moisture may be artificially dried. Temperatures in the drier should not exceed 100° F.

Paddy rice may be handled safely in bulk or in sacks if the moisture content is below 15 per cent.

Fractures, called sun-checks, are caused by high temperatures at the time of drying rather than merely by exposure to the sun. Temperatures of 120° to 130° F are commonly found in parts of shocks and windrows that are exposed to the sun. These high temperatures cause too rapid drying of the rice kernels, which, in turn, produces sun-checks. The percentage of sun-checking is considerably higher in these exposed parts.

Sun-checking in brown rice is a fair, though not a positive, indication as to what milling yields may be expected.

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